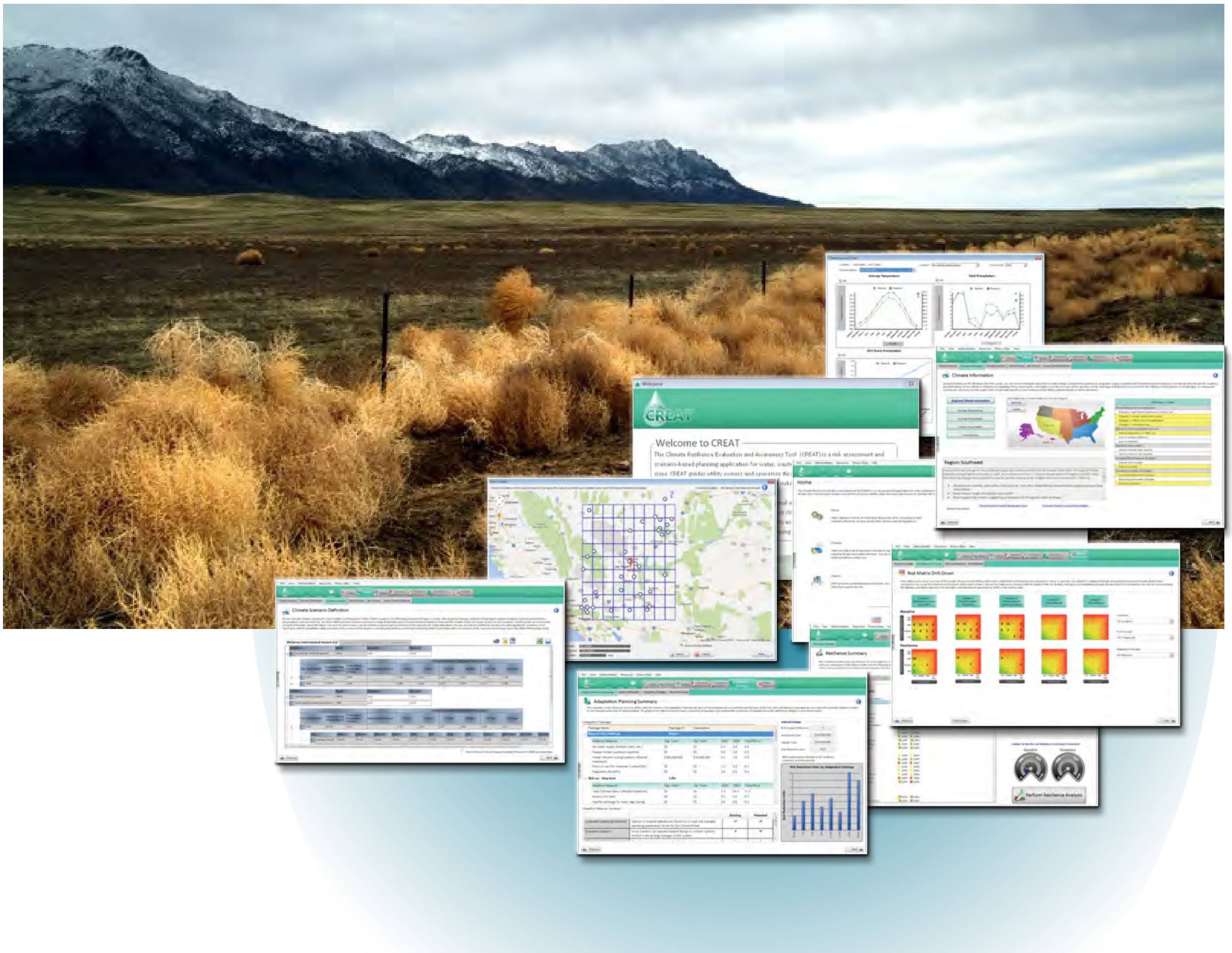
United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES

Climate Resilience Evaluation and Awareness Tool 2.0 Exercise with Southern Nevada Water Authority



United States Environmental Protection Agency

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EPA

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EXECUTIVE SUMMARY

The mission of the Southern Nevada Water Authority (SNWA) is to manage the region's water resources and develop solutions that will ensure adequate future water supplies for the Las Vegas Valley. Historically, drought and large population growth have stressed water management in this region of the country. Recently, due largely to concerns about the additional impact of climate change on current drought conditions, the SNWA participated in an exercise with the U.S. Environmental Protection Agency (EPA) to demonstrate use of the recently released Climate Resilience Evaluation and Awareness Tool (CREAT) version 2.0 by beginning an assessment of overall risks to its system and identifying opportunities for adaptation. Through a series of internal collaborations and webinars with EPA, SNWA participants discussed their approach to a risk assessment and began collecting information related to available climate data, anticipated climate change impacts and potentially vulnerable assets.

The exercise, which took place over approximately three months, culminated in a two-day in-person exercise. SNWA participants considered impacts across three potential climate scenarios, based on the projections provided within CREAT, in two future time periods (2035 and 2060). Informed by these projections, participants defined numerous threats under each scenario and time period and conducted a preliminary risk assessment for only the most relevant priority assets. As part of this exercise, SNWA participants identified more than 60 current and potential future actions to take in response to climate change.

Major accomplishments of the exercise included: obtaining a range of future climate projections to consider, identification of priority threats and assets, completion of a preliminary risk assessment and increased understanding and consensus building around key risk assessment parameters (e.g., likelihood, consequences, climate data). Moving forward, SNWA is considering using the consequence matrix and climate scenarios defined through this exercise with an updated, more comprehensive database of its threats, assets and adaptive measures. Based on the lessons learned during the exercise process, SNWA participants plan to revisit their threat selection under each scenario, refine asset-threat pairing selections and preliminary risk assessments and begin the design of packages to consider as possible adaptation plans. Another benefit from this exercise was the opportunity to provide important feedback to EPA regarding how utilities approach and use the tool.

BACKGROUND

Southern Nevada Water Authority (SNWA) is a cooperative of seven member agencies founded in 1991 with the collective mission to manage the region's water resources and develop solutions that will ensure adequate future water supplies for the Las Vegas Valley. Drinking water is primarily (nearly 90%) sourced from the Colorado River via Lake Mead and processed through two water treatment plants to provide for Las Vegas valley residents and businesses. Groundwater production provides additional water supply during summer months. Recent extended drought has increased the challenge of continuing to provide a sustainable supply of water. In response, over the past two decades, SNWA has implemented an effective water resource plan[1] focused on water resource diversification through demand management, development of interim and in-state water resources, as well as efforts to address the uncertainty of the ability of the Colorado River to meet future demand. In addition to the uncertainty of future growth (and therefore demand forecasts) and existing drought challenges, SNWA must cope with uncertainties related to how climate change may impact the supply of and demand for water resources. To help assess future supply and demand imbalances for the region as well as potential solutions to those imbalances, the US Bureau of Reclamation, in collaboration with Basin States[2], supported and participated in the Colorado River Basin Water Supply and Demand Study[3] from 2010 to 2012. The study considered four Colorado River water supply scenarios that took into account two major uncertainties: changes in stream flow variability and changes in climate variability and trends. When considered as averages across multiple supply and demand scenarios for the region, the study found a median supply and demand imbalance of 3.2 million acre feet by 2060. In the past, Colorado River droughts and subsequent reductions in water supply have been largely dealt with by tapping in to reservoir storage supplies. However, from 1999-2008, average inflow from the Colorado River was 66% of normal resulting in storage of only 52% of total capacity in the primary reservoirs[4]. With reservoir levels continuing to drop since 2008 due to drought conditions, SNWA has pursued multiple strategies to manage water resources including enacting drought contingency plans, including development of additional water resources and increased conservation measures. Due to the concern of continued drought and potential exacerbation of water management issues by climate change, SNWA is taking additional action to assess and respond to potential system vulnerabilities.

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[1] Southern Nevada Water Authority Water Resource Plan online at http://www.snwa.com/ws/resource_plan.html.

[2] Basin States are Wyoming, Colorado, Utah, Nevada, New Mexico, Arizona and California.

[3] Hereafter referred to as “Basin Study” in this report. Information and links to study documents can be found at http://www.usbr.gov/lc/region/programs/crbstudy.html.

[4] Lake Mead and Lake Powell, as described in 2009 Southern Nevada Water Authority Water Resource Plan.

EPA's Climate Resilience Evaluation and Awareness Tool (CREAT) version 2.0 was developed to help water and wastewater utilities evaluate and assess the potential impacts of climate change on utility system assets. CREAT 2.0 includes three climate scenarios for every location in the U.S., based on available climate projections to assist utilities in scenario planning to support robust decision making. By guiding users through a decision-making framework, CREAT helps utilities understand risks and assess opportunities to reduce risks from future climate impacts. The CREAT framework is flexible and can support utilities at any stage in the risk assessment process, from those considering only a few priority assets to those pursuing a more complex assessment of assets and threats across a range of climate scenarios and time periods.

EXERCISE GOALS AND PROCESS

SNWA partnered with EPA in an exercise to conduct a full risk assessment using CREAT 2.0 to determine the potential impacts of climate change on its operations and identify adjustments to management of future water supplies. Specific exercise goals included using CREAT to:

- Obtain a range of future climate projections for the Las Vegas Valley for both short- and long-term time periods (i.e., 2035 and 2060)
- Identify the assets most vulnerable to weather and climate-related threats, based on climate projections
- Develop cost-effective adaptation strategies to minimize threats using the CREAT-provided risk reduction unit (RRU) metric and demonstrate resilience (or lack of resilience) to future climate threats both with and without adaptation.
- Familiarize staff with the climate change risk assessment process and develop a database file including SNWA assets, threats and adaptive measures for use in future assessment iterations.
- Develop a report of process and findings.

EPA introduced participants to the CREAT software and risk assessment process (Figure 1) over a series of two webinars. Between webinars, SNWA participants collaborated through subgroup meetings and used Excel spreadsheets to facilitate data collection. Ongoing productive discussions constantly refined the data being input. The exercise culminated in a two-day in-person event at SNWA which provided an opportunity for participants from SNWA and the Las Vegas Valley Water District (LVVWD) to conduct assessments as a group, build and discuss potential adaptation packages and identify a path forward for future work (Appendix A).

Figure 1. CREAT process

Progress and Accomplishments

During this exercise, SNWA completed a preliminary risk assessment to assist with climate change and adaptation planning. CREAT provided relevant climate data and a framework that facilitated discussion and assessment of specific threats on priority assets. Participants gained a more thorough understanding of the climate data, the risk assessment process and how to think strategically about adaptation despite an uncertain future. The first three steps of the CREAT process – Setup, Threats and Assets – provided an important opportunity for SNWA to collect and organize relevant data and make key decisions related to its analysis parameters including the use of climate scenarios. To date, specific accomplishments include: identification of analysis parameters, selection of climate data to use in analyses, identification of priority threats, identification of vulnerable assets, completion of baseline and resilience analyses for priority asset/threat pairs, documentation of existing and potential adaptive measures and preliminary design of adaptation packages.

Setup

The Setup step of CREAT provides users with the opportunity to catalog basic utility information and to customize their assessment in terms of locations considered and desired analysis parameters. CREAT allows users to select between one and four locations for analysis. The location feature helps users understand the scale at which climate projection data are being provided before beginning assessments and can help determine where impacts should be assessed. The ability to utilize climate projection data from multiple locations is particularly important for utilities that have geographically widespread assets and for those that depend on large watersheds for system supply (Figure 2).

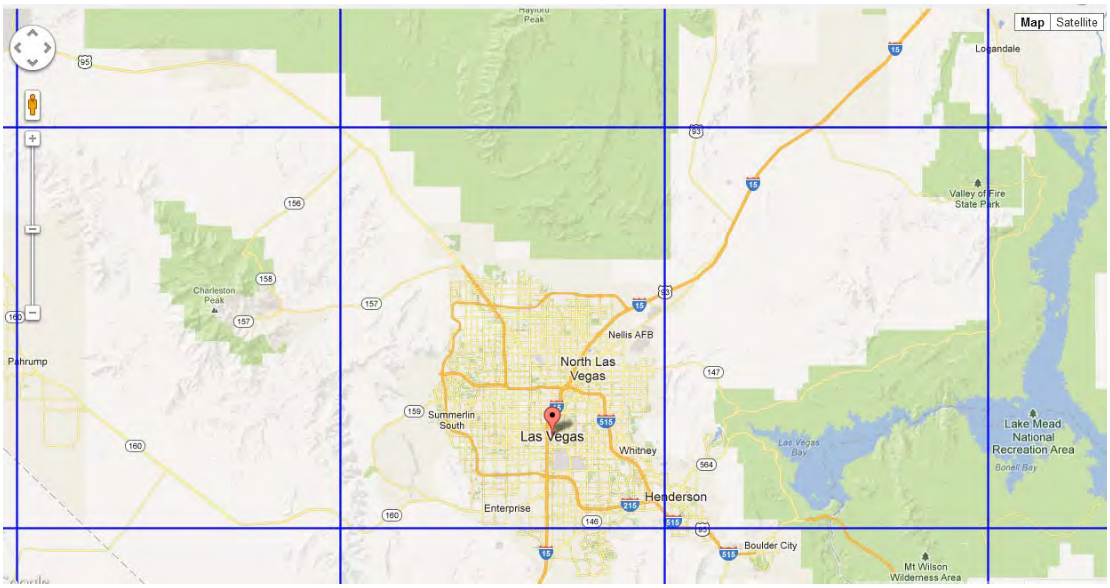

Figure 2. Map of SNWA's primary operating area with overlay of CREAT-provided grid cells at 0.5 by 0.5 degrees, also the resolution of climate data.

CREAT users can select from pre-loaded NOAA weather stations or provide their own data for historical annual and monthly temperature and precipitation. During early discussions, SNWA participants considered four separate locations representing strategic areas of both lower and upper portions of the watershed (e.g., McCarran Airport; Las Vegas Wash; Ely, NV; and Fontenelle Dam). However, the group decided to focus on the McCarran Airport location which is closest to its customer base and drinking water facilities and is the site SNWA relies on for weather data. One parameter, daily maximum temperature, is an important metric used by SNWA for planning but is not provided in CREAT and therefore wasn't used as part of this assessment.

There were also slight differences between the historical data provided by CREAT and that typically used by SNWA from the McCarran station. These minor differences result from the fact that historical average data in CREAT are based on multi-station averages by grid cell as provided in the Parameter-elevation Regressions on Independent Slopes Model[5] (PRISM), whereas SNWA historical data is sourced directly from one individual weather station. In addition, the historical intense precipitation data are based on a curve fit to a Generalized Extreme Value curve. Differences between CREAT-provided and other data sets are likely due to methodological differences (e.g., rules for excluding data outliers, years included in the data set and curve fit method). After reviewing the CREAT-provided data and comparing to its own data, SNWA opted to use the data provided from the McCarran station. Within CREAT,

[5] The PRISM Climate Group website is http://www.prism.oregonstate.edu/.

selection of historical data is important because this designates the data set to which changes in climate (projection deltas) will be applied.

In addition to accommodating utility weather and climate data sets, CREAT also gives users flexibility in how they may approach the two standard components of risk: likelihood and consequence. These decisions are made during Setup and applied uniformly to all subsequent analyses. For likelihood, there are two options. Users can choose to assess the likelihood of various climate-related threats on a four-point qualitative scale (from Low to Very High) or they can simply assess each threat as if it would occur by using conditional likelihood, which sets all likelihood assessments to Very High (i.e., providing a 'what-if' approach). It is important to note that within CREAT likelihood refers specifically to the likelihood of a threat occurring given a certain climate scenario (e.g., likelihood of lower lake levels assuming the Hot and Dry scenario occurs). The likelihood assessment does not imply that users can assess how likely climate is to change, rather that under specific projected conditions, they can assess the likelihood of particular impacts or threats (e.g., if temperature rises 3 degrees and precipitation drops by 5%, how might this impact source water availability). The ability to assess threat likelihood is greatly improved when threats are explicitly and quantitatively defined. In some cases, this requires the help of tools and datasets outside of the CREAT process. During initial discussions, SNWA elected to consider the likelihood parameter within its risk assessment. However, during the in-person exercise SNWA also ran a sensitivity analysis by switching the likelihood setting to conditional and reviewing how this changed overall risk results.

The review and refinement of consequence categories and weightings is also an important determination within Setup that impacts analysis results. CREAT provides five categories representing the different types of consequences a utility might face from climate-related impacts. These categories include: Utility Business Impacts, Utility Operational/Equipment impacts, Source/Receiving Water Impacts, Environmental Impacts and Community/Public Health Impact (Figure 3). Within the tool, users can modify these categories, their definitions and the weights assigned to them. Category definitions are significant because they are used to systematically assess consequences for all threats on all assets. Following discussion, SNWA refined its consequence categories; those related to business, source water, and community health impacts were defined in terms of capital investment costs, water shortage duration and loss of life, respectively. Quantification of consequence levels for equipment impacts was based on insurance deductibles (Appendix B).

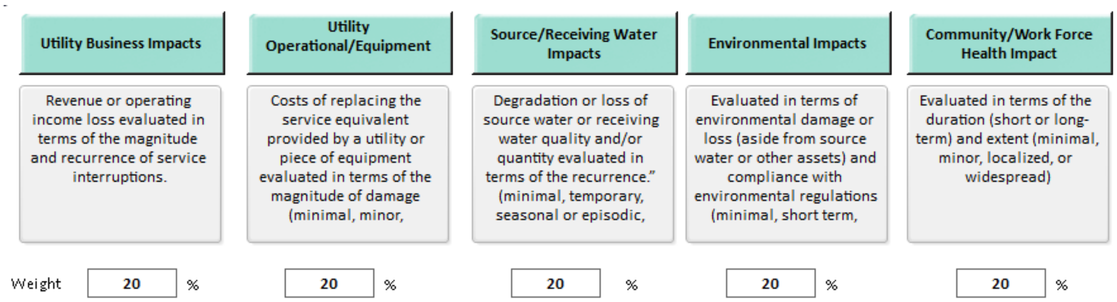

Figure 3. Consequence categories and definitions as provided within CREAT.

In addition, the option to weight different categories equally, variably or to use the highest-level consequence category for each asset/threat pair being analyzed gives utilities the opportunity to further customize their parameters. Equal weighting essentially implies that the utility views consequences in all five categories as equally debilitating to their environmental and public health missions; whereas, weighting some categories more heavily than others reflects where a utility is unwilling to accept losses. In contrast, those categories weighted less heavily reflect areas where a utility is willing to accept some losses. Within its analysis, SNWA chose to accept the default of equal weighting across consequence categories. However, as with likelihood, they were curious about the sensitivity of results to this setting and they explored the effect of using the highest weight setting for consequences on their analysis results.

Threats – Climate Scenarios

CREAT allows users to consider threats to utility assets under different climate scenarios as part of the risk assessment process. Within CREAT, scenarios are defined as projected changes in climate with respect to average conditions (temperature and precipitation), extreme events (intense precipitation) and sea-level rise (not applicable to SNWA analysis). For each user-defined location, CREAT provides three scenarios that represent a range of potential future climate conditions. The method used by CREAT for climate model selection is described in the CREAT v2.0 Methodology Guide, available in the software downloaded from the EPA CREAT website[6]. Climate model results are plotted in terms of their projected average annual change in temperature and precipitation for each location in the 2060 time period (Figure 4).

[6] http://water.epa.gov/infrastructure/watersecurity/climate/creat.cfm

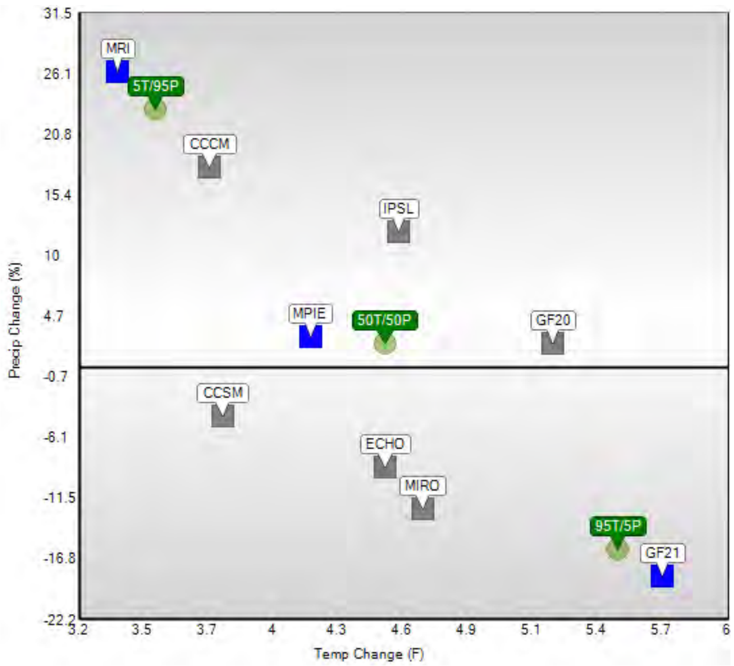

Figure 4. Scatter plot showing the range of model projections (squares with model name in each flag) for the SNWA McCarran airport location in terms of changes in temperature (in degrees Fahrenheit) and precipitation (as percentage) relative to today's conditions. Green circles indicate statistical targets (with temperature and precipitation percentiles in each flag), while blue squares show selected model projections for this location.

CREAT calculates statistical targets based on the distribution of projected changes in temperature and precipitation (95th percentile temperature /5th percentile precipitation, 50/50 and 5/95) and then selects the model closest to these targets. These models represent a future that relative to today tends to look hot and dry (i.e., increase in temperature, decrease or minimal increase in precipitation), warm and wet (i.e., some increase in temperature, but greater increase in precipitation) and a central model projection between these two outer bounds. These projected conditions are based on the projected changes applied to the historical data provided by exercise participants (Table 1). This method of applying model projected changes to user-provided historical conditions gives users a consistent comparison between current and projected conditions founded in their experience and informed by climate model data.

Table 1. SNWA defined historical data for defining scenarios.

	Average Temp (F)	Total Precip (inches)	Total precipitation (in) during 24-hour event					
			5-year	10-year	15-year	30-year	50-year	100-year
Annual	68.10	4.49	1.18	1.42	1.54	1.73	1.89	2.09
JAN	47.00	0.59	0.75	0.91	0.98	1.14	1.26	1.38
FEB	52.20	0.69						
MAR	58.30	0.59						
APR	66.00	0.15	0.55	0.79	0.91	1.18	1.38	1.73
MAY	75.40	0.24						
JUN	85.60	0.08						
JUL	91.20	0.44	0.79	1.22	1.54	2.17	2.8	3.98
AUG	89.30	0.45						
SEP	81.30	0.31						
OCT	68.70	0.24	0.75	0.98	1.1	1.3	1.46	1.69
NOV	55.00	0.31						
DEC	47.00	0.40						

The purpose of providing multiple scenarios within CREAT is to help users grapple with the uncertainty inherent in all climate projections. Considering the range of possible conditions often facilitates identification of worst-case scenarios and prioritization of assets and threats that should be examined in greater detail. In regards to their risk assessment, SNWA wanted to consider multiple scenarios and choose to adopt the CREAT-provided Hot and Dry, Central and Warm and Wet scenarios within their analysis file. The decision to adopt the CREAT data, even though SNWA also had data available from the Basin Study, was based on the fact that both use the same available climate models in their analysis[7]. Because of the high percentage of overlap, the adoption of CREAT data was deemed the most efficient path forward. Within each scenario, users can consider impacts in both mid- and long-term time periods. Specifically, CREAT provided SNWA with projected conditions for 30-year periods centered on 2035 and 2060.

The temperature and precipitation data used as the three scenarios in CREAT are provided in Appendix C. Going forward, SNWA may opt to switch historical data sets to adjust the baseline climate while still using the CREAT-provided scenarios. The average condition data was based on data collected and used by SNWA. The intense precipitation data provided in CREAT for the same station (COOP 264436) was adopted as part of the historical climate data set.

Under each climate scenario, SNWA defined more than a dozen possible threats for analysis (Table 2). Many of the climate-related threats of concern for SNWA are those occurring as a

[7] Data from World Climate Research Programme (WCRP) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset. Available online at http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/

result of climate conditions outside the service area, specifically drought in the Colorado River Basin which largely controls Lake Mead reservoir levels and changes in reservoir water quality (e.g., concentrations of total dissolved solids, bromide and total organic carbon). Defining threats within CREAT involved the identification of specific parameters such as the magnitude of concern, changes through time and an assessment of the likelihood of each threat under each scenario (Appendix D).

Table 2. SNWA-defined threats for application in CREAT risk assessment. Threats with * were part of priority analysis.

Threat	Description
* Low Lake	1075-1000 ft are trigger levels to shortage (13,000 to 20,000 acre-feet per year) on CRB Note: Below elevation 1025, shortages may exceed 20,000 acre-feet per year.
* Extreme Low Lake	<1000 ft amsl - Loss of capacity to draw water
* Warm H2O	Warm water inflow and/or warm water in distribution system
H2O Demand	Changing evaporative demand for residential/commercial landscapes may cause consumptive use to rise. Greater system demand. Rising maximum daily temperatures, increasing number of extreme heat days may impact peak demand during summer months. Lengthening of the (Landscape) growing season is expected.
H2O Quality	Separate from warm water to include changing concentrations of TDS, Bromide and TOC
Pwr Grid	The number of cooling degree days are expected to rise (and the number of heating degree days will fall), causing increased strain on the power grid.
Pest	Invasive species
Fire	Rise in wildfires
Flood	Extreme flooding
GW recharge	Reduced groundwater recharge
Runoff time	Change in timing of runoff (Distribution volume and temperature challenges)
Snow	Reduced winter snowpack accumulation
Wetlands	Loss of wetlands
High Temps	Higher working temperatures
High H2O Cost	Increasing cost of water
Unhealthy Environment	Unhealthy environment (air quality i.e. high ozone or high particulate levels)
Living Cost	Higher cost of living (power, gas, food, medical care, etc.)

During the exercise, SNWA focused on the scenario of greatest concern given recent drought trends, the Hot and Dry Scenario. Due to the critical nature of drought, participants opted to include both lower lake levels (1000-1075 ft), and extreme lower lake levels (<1000 ft) as threats to the Lake Mead water resource. Instead of basing the definition of these threats on the CREAT-provided climate scenarios, SNWA used information available from the Basin Study on projected changes in lake levels associated with similar projected climate scenarios. Although low lake levels have historically resulted in water quality challenges, the warmer water threat was explored within the assessment to a limited extent because of the lack of supporting quantitative data available during the exercise.

Assets

SNWA participants cataloged numerous assets related to their water and environmental resources, infrastructure and personnel that might be impacted by climate-related threats within CREAT. However, during the discussion of scenarios and threats, they recognized the need to keep the number of analyses within scope and were able to exclude cataloged assets from analysis. Assets were prioritized based on having three characteristics, 1) the asset is critical to achieve SNWA's mission, 2) the asset has been sensitive to climate parameters historically, and 3) there are potential adaptation options available to SNWA that could minimize risk. Priority assets were easily identified with the priority threats of reduced lake levels and warmer water. Furthermore, SNWA prioritized three asset/threat pairs for assessment to understand the impact of lower lake levels on the Lake Mead asset and warmer water on the water treatment system asset.

Risk Assessment

In contrast to the previous steps in the CREAT process, the risk assessment steps guide users through an assessment process for each asset and threat. These assessment results provide the data needed to gauge effectiveness of adaptation and develop plans. The results presented within this section of the report are demonstrative of the tool process and should not be taken as a final risk assessment for SNWA assets.

During the second webinar, the Baseline Analysis steps in CREAT were conducted using the asset/threat pair of Lake Mead intakes and lower lake levels. In CREAT, Baseline Analysis consists of three steps:

(1) Identify existing adaptive measures – These measures include any actions or infrastructure planned or currently being used to reduce the consequences of a threat on an asset. For the example, SNWA indicated that it is already conducting demand management practices and constructing a new intake (by 2014); both of which were included as existing measures.

(2) Assess consequences – For each asset/threat pair and time period, the severity of impact for each of the consequence categories can then be assessed. The group assessed the overall impact as medium, but did not resolve the level by category. The levels for each category were set to medium for demonstration purposes with the agreement to revisit later.

(3) Review results – In the final step of baseline; CREAT provides a summary of results for the impacts of lower lake levels on the Lake Mead asset. Results display the overall qualitative metrics for likelihood, if applicable, and consequence. All steps provide optional comment fields to capture any assumptions or rationale used during assessment.

Similarly, a preview of the Resilience Analysis steps in CREAT was provided with the asset/threat pair of Lake Mead intakes and lower lake levels. Resilience Analysis in CREAT consists of four steps:

(1) Identify potential adaptive measures – Unlike Baseline Analysis, potential measures are defined as any additional actions that are possible to reduce the consequences of a threat on an asset. In lieu of any specific measures ready for discussion, the concept of a hypothetical 'Healthy-sized Water Resource Acquisition' was used as a placeholder.

(2) Adjust consequences – The assessment of consequences in Resilience Analysis is an adjustment of the baseline consequences to a new level based on any changes once potential measures are implemented. This assessment is a "what-if" assessment of the gains attributable to adaptation. In this case, consequences from lower lake levels would decrease with the addition of the hypothetical water resource acquisition.

(3) Assign adaptive measure contributions – Each potential measure used receives a fraction of the 'credit' for assessed reductions consequences following implementation. Some measures may provide a larger gain in resilience than others and providing these fractions better informs decisions when considering performance of adaptive measures across several assets and threats. For this example, the single measure used is assigned 100% contribution.

(4) Review results – As in Baseline Analysis, CREAT provides a summary of all risk assessment results for this asset/threat pair.

The baseline analysis results give a snapshot of projected risks in future time periods (2035 and 2060) if SNWA continues business as usual, but takes no additional action to adapt to climate change. The majority of the work related to SNWA assessments on priority asset/threat pairs was conducted during the in-person portion of the exercise (Appendix E) which allowed for group discussion and consensus building related to consequence assessment and adaptive measure contribution. As part of the work between events, SNWA completed a baseline analysis for each priority asset/threat pair in both time periods of the Hot and Dry scenario. Results are displayed for equal weighting of consequence categories (Figure 5).

As part of the baseline analysis process, participants brainstormed those utility practices that could be considered adaptive measures. Collectively, participants identified more than 60 existing and potential adaptive measures for potential use in its assessments (Appendix F). The group used an iterative process to populate information (i.e., descriptions, relevant threats and costs) with respect to these adaptive measures within CREAT. Qualitative or quantitative cost information for both initial capital and operation and maintenance were provided to the extent possible.

In the initial baseline analysis results, many threats were assessed as an overall low risk. Upon re-visiting these assessments, participants noted that the low risks were a result of the consequence weighting method which was set to equal across all categories. For example, for the extreme low lake levels threat, even though the consequence assessment for the source/receiving water category was rated high, the low consequence rating of the four other consequence categories produced an overall consequence assessment of low. To better understand how consequence weighting methods impacted results, SNWA produced multiple versions of its analysis results using different settings. From this point on during the exercise, the highest-level setting was used to reveal the overall higher levels of consequence assessed for each category.

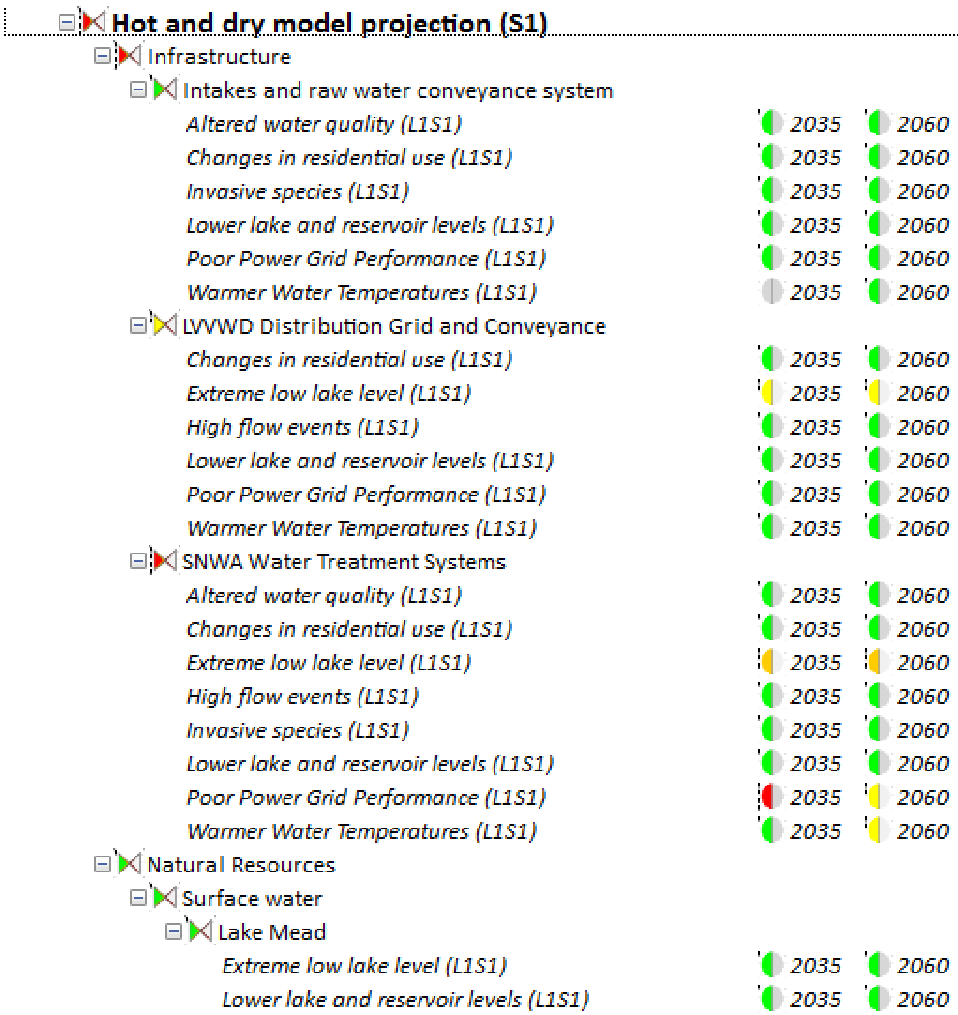

Figure 5. Preliminary baseline analysis results for all asset/threat pairs in the Hot and Dry scenario using the weighted sum method of consequence assignment.

Additional assessment during the in-person exercise focused on resilience analysis for priority asset/threat pairs in the Hot and Dry scenario. Specifically, participants discussed and assessed adaptation options to reduce the threat of extreme low lake levels on Lake Mead and the threat of warmer water temperatures for their water treatment process. To address the issue of drought-induced extreme low lake levels, participants proposed a variety of adaptive measures including: using groundwater to augment supplies, optimizing use of the third intake, strengthening existing measures (demand management, leakage reduction, drought contingency plan), maintenance of interim supplies (bank recovery and/or ICS), re-allocation (as designated in the Colorado River Basin Study report) as well as modeling supply and demand and monitoring weather. With these options in place, the group adjusted consequences for the source/receiving water category from high to low (i.e., seasonal or episodic impacts would be reduced to minimal impacts).

The rationale for the contribution of each adaptive measure to the overall reduction in risk was based on the ability of each to make up the resource lost with groundwater resources and interim supplies contributing the most (>50%). The group also elected to include access to the Las Vegas Valley groundwater bank as a short-term bridging resource (a potential measure), but set its risk reduction contribution to zero percent to reflect the limited amount of water available for withdrawal in any given year. Inclusion of this measure within the analysis was for the purpose of keeping track of all options to respond to drought-induced lower lake levels.

The group also discussed and assessed options to reduce the consequences of warmer water temperatures on its treatment system. To address the medium level risk for 2035 (as determined in the Baseline Analysis), participants proposed well-use optimization and accessing groundwater supplies as bridging efforts. Research to help identify critical factors would be low-cost and could be pursued to help refine existing efforts. Following these bridging efforts, the group proposed that altering treatment by increasing the use of air stripping would be pursued until addition of chloramination became more economical. Further alteration of treatment processes, such as through the installation of influent cooling systems and use of advanced treatment (i.e., reverse osmosis or microfiltration) would only be considered as a last resort. Other last resort options included engaging in discussions of regulatory flexibility and point-of-use treatment. With this full suite of measures in place, the group assessed that risks would drop to a low level of consequence. Although resilience analyses were only completed for a few conditions, the process was instructive and the preliminary results are presented in Figure 6. Participants noticed that although the first assessment was rather difficult, subsequent assessments became easier as the group increased its comfort and familiarity with the process.

Adaptation Planning

Adaptation Package Design

Adaptation planning refers to the process of considering potential impacts from climate change and developing strategies to address those impacts. Comparison of different options includes taking a critical look at costs, the time required to implement different measures and an assessment of how effective these options may be in mitigating consequences. Using the results of the baseline and resilience analyses, the tool calculates risk metrics (i.e., risk reduction units or RRUs).The comparison of different packages of adaptive measures is done within the Adaptation Planning tab. Adaptation packages in CREAT do not necessarily need to be discrete as long as users understand how to compare them. For example, package design may reflect funding availability, represent a tiered approach to adaptation or focus on specific portions of the system. SNWA participants elected to pursue the development of packages based on ‘trigger points’ which align with their general approach to planning (i.e., pursue lower cost options first and consider additional actions when certain thresholds or trigger events are reached).

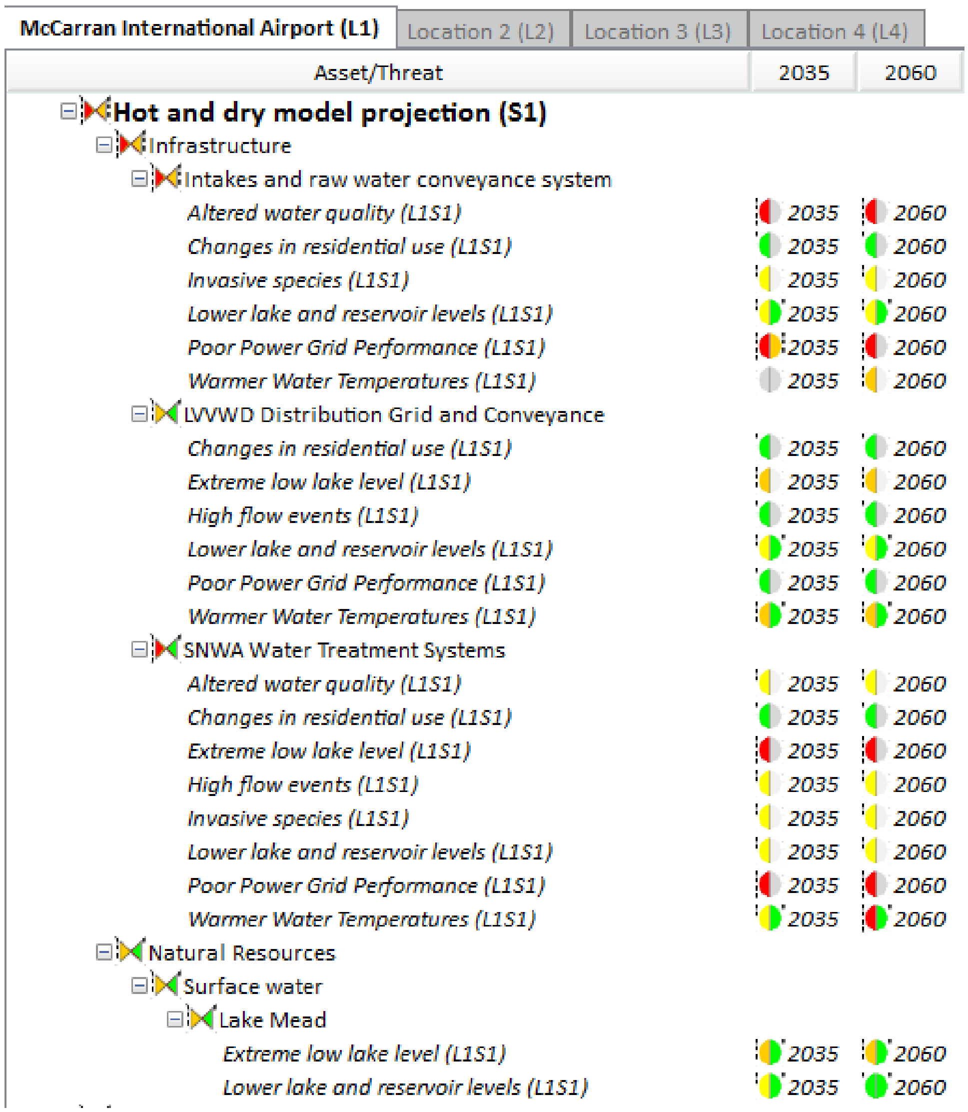

Figure 6. Refined preliminary baseline analysis results (*using highest level consequence method*) and resilience analysis results for priority asset/threat pairs.

SNWA designed five adaptation packages to address two main threats: challenges related to water quality and challenges related to temperature management in the distribution system. Four of these packages included short- and long-term solutions to these respective issues, while the fifth package included last resort measures. The types of triggers for each package were identified, although the exact thresholds are yet to be determined (Appendix G).

Preliminary CREAT Results

Assessment results are presented in CREAT through three types of data displays within the Results tab. The results summary screen shows an overview of progress within the tool by displaying a risk profile and a risk index. The risk profile is a series of stacked bars that display baseline and resilience results in each defined scenario. The risk index graph shows two overlaid bars that illustrate how much resilience is gained in each scenario via the difference between baseline and resilience results. Displays can be modified to show results from select locations, time periods or adaptation packages.

Following the conclusion of the in-person exercise, preliminary results indicated that SNWA may experience a broad range of climate impacts with the most severe consequences occurring in the Hot and Dry scenario. Because assessments to date have focused on prioritized asset/threat pairs in a single scenario, it is difficult to assess the potential for adaptation (the ability to gain resilience through remedial actions) across scenarios. Although preliminary baseline analyses were conducted for all three scenarios, SNWA may choose to revisit analyses conducted in the Central and Warm and Wet scenarios at a later date to ensure that the thought process and assumptions are consistent with those for the Hot and Dry scenario.

In this particular case, the results summary screen may be less instructive when the weighted sum method is used because of the high number of asset/threat pairs that have low baseline consequence results. This situation provides few opportunities for users to assess improvement during the resilience analysis. In order to reveal assessments where higher consequence levels were assigned to individual categories, you can either choose to weight certain categories at a higher percentage or select the highest-level option during Setup. Switching to highest-level option provided more results with high and very high consequences to address through implementation of adaptive measures during resilience analysis (Figure 7).

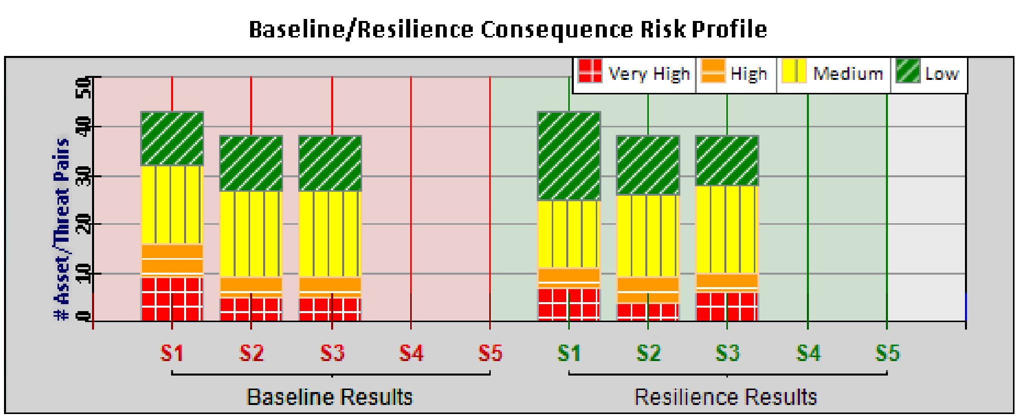

Figure 7. The SNWA risk profile under highest level consequence method shows improvement going from Baseline to Resilience, illustrated by a greater number of asset/threat pairs with low risk (green) and fewer with high and medium risk (orange and yellow) for Scenario 1. Scenarios 2 and 3 show inconsistent results because no resilience analyses were conducted.

The second type of result display, the risk index graph, currently provides minimal information because not all asset threat pairs with a baseline analysis have a corresponding resilience analysis and therefore the RRU values provide an incomplete representation of potential resilience gained. The power of this graphic will be more apparent once the full risk assessment is complete and it can be used to help understand the relative risks under different climate scenarios and the potential to reduce risks through adaptation (Figure 8).

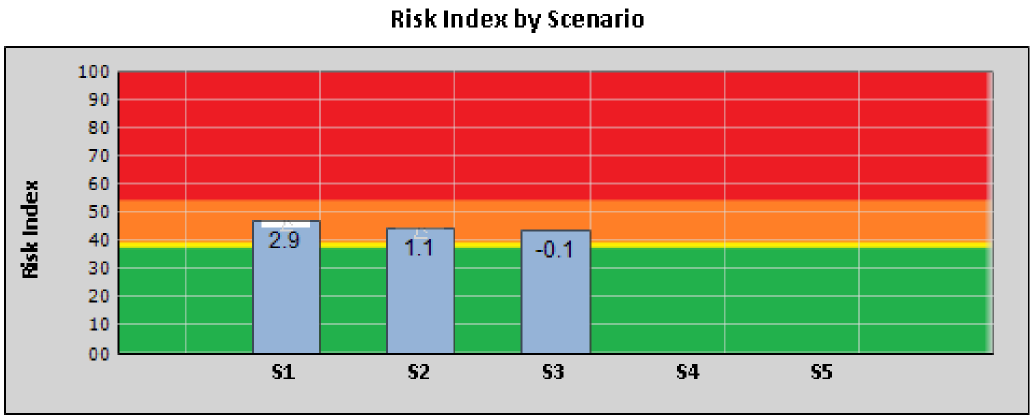

Figure 8. The SNWA risk index by scenario (S1 through S5 on axis) shows some potential for reducing overall risk levels (blue bars) through adaptation for each scenario. Additional resilience (inset white bar in S1) will become apparent upon completion of the remaining assessments and any refinement of existing assessments.

Results for each analysis are also presented on the risk matrix drill down tab. This tab includes a series of 4-by-4 risk matrices which display the number of asset/threat pairs in each combination of likelihood (from low to very high) and consequence (from low to very high). Comparing the numbers between baseline and resilience analyses within each scenario, it is desirable to see numbers shift from right to left, indicating a reduction in the consequences due to the implementation of adaptive measures. For climate risks, it is very unlikely that users will be able to locally influence the likelihood factor for risk and therefore there is no shift anticipated from top to bottom within the matrices. Preliminary SNWA results show similar patterns in baseline results across scenarios, with a clustering of assessments of high likelihood and medium consequence. Available results in the resilience matrices indicate a shift towards lower consequences (Figure 9). However, the main purpose of this screen is to compare the movement between baseline and resilience within individual scenarios, which is difficult to do given the incomplete assessment status and without knowing which specific asset threat pairs fall into each category and comparing them one to one. Once all assessments are complete, it will be much easier to detect patterns and identify solutions that are effective across scenarios.

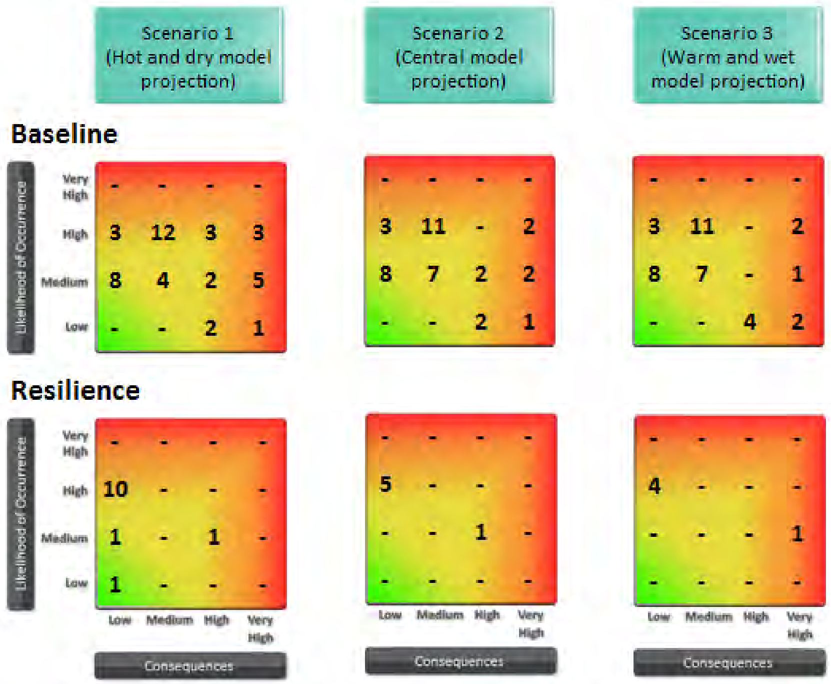

Figure 9. Preliminary risk matrices under highest-level consequence weighting method. The presence of multiple asset threat pairs in the very high category for consequences is the result of just one category being assessed as a very high consequence. These results do not reflect the final risk assessment and are meant to demonstrate the display within CREAT.

Status and Lessons Learned

Current Status

The majority of exercise goals have been accomplished, including the following.

- SNWA obtained a range of future climate projections for the Las Vegas area for both mid- and long-term time periods (i.e., 2035 and 2060).
- SNWA identified the assets most vulnerable to weather- and climate-related threats based on climate projections.
- SNWA partially completed the third goal by conducting resilience analyses for two asset/threat pairs; for each pair, participants developed cost-effective adaptation strategies to minimize threats using the CREAT-provided risk reduction unit (RRU) metric and demonstrated resilience (or lack of resilience) to future climate threats both with and without adaptation.

- SNWA participants have a good understanding of the risk assessment process and have developed a CREAT database file that includes SNWA assets, threats and adaptive measures that can be used for reference and to help support future assessment iterations.

In addition to these goals, SNWA completed a preliminary assessment of risks from climate impacts based on local climate projections, as well as asset and threat prioritization (an important early step in the CREAT process). SNWA also accomplished consensus building among its diverse group of participants regarding consequence categories, use of climate data, contribution of adaptive measures, prioritization of threats and assets and discussion of adaptation planning. All of these decisions are critical parts of the CREAT process, and building consensus on these decisions gives greater weight to and a sense of wider ownership of the results of the analyses.

Lessons Learned

Throughout the exercise, participants developed an understanding of how to use CREAT to conduct a risk assessment and identified key questions to address in future planning sessions. During this process, some of the more challenging steps within the CREAT process provided an opportunity for participants to question existing assumptions, refine use of terminology, understand the differences between different analysis parameters in CREAT (e.g., likelihood and consequence weighting) and think critically about the definition of threats and the assessment of consequences from those threats. Participants provided important feedback regarding their process and recommendations for future CREAT users including the following:

- Risk assessments can be conducted in many different ways. It is important that a utility have a clear sense of its goals and how to accomplish them within the software and that the utility reference the appropriate worksheets and other materials to aid in key decisions related to data population. It is generally easier to start small and build out than to start with a large data set and narrow it down.
- Creating scenarios and defining meaningful threats under each (e.g. details about the magnitude or frequency of a threat) is a necessary precursor to the risk assessment process. Additionally, utilities may want to identify other tools and models that can inform the CREAT analysis process (e.g., hydrologic or water quality models that have temperature or precipitation as input parameters).
- Users may need to consider the time necessary to implement adaptive measures (planning versus implementation).
- Within risk assessment, the adaptive measure contribution step was challenging. Specifically, users need guidance on how to capture high-cost or last-resort options, how to incorporate the likelihood of adaptive measures into this decision, how co-benefits are captured within the two and feel comfortable deciding when to lump and when to split adaptive measures.
- In some cases, users may need to consider unintended consequences of adaptation packages (impacts and consequences that are not covered by external costs).

- Additional suggestions related to future tool development and training exercises are cataloged in Appendix H.

Conclusion and Next Steps

SNWA described its progress to date as 'a good first cut general assessment to be followed up with a more comprehensive assessment'. SNWA foresees the potential to use additional locations if the assessment extends to its other water purveyors and possibly to the flood control district. In the short-term, SNWA plans to refine its approach to the use of scenarios by:

- Revisiting threat selection and definition for each scenario and revisiting which assets are designated as vulnerable or as priorities under these conditions;
- Including any underlying assumptions about what low lake levels mean in terms of dissolved oxygen (DO), turbidity, mixing, and overall water quality and supply; and
- Differentiating threats by the adaptive measures that can be applied to them.

Based on the newly defined scenarios (that is, groups of threats), SNWA will revisit baseline and resilience analyses with the new information on threats and any available information on likelihood of implementing adaptive measures. SNWA will then generate results using the revised data, and its adaptation planning may also be revised pending results and adaptive measure cost data. SNWA plans to complete a more comprehensive climate change vulnerability assessment using CREAT at a later date based on a completed analysis for all priority asset/threat pairs to report the relative RRUs and cost per RRU information to aid in decision making and additional more detailed work in planning for the future.

APPENDIX A - EXERCISE PARTICIPANTS

Keely Brooks – Climate Change Policy Analyst (SNWA)

Keiba Crear – Manager Environmental Monitoring and Management (SNWA)

Rick Holmes – Senior Strategic Advisor (SNWA)

Kevin Fisher – Director-Operations (LVVWD)

Laura Jacobsen– Planning Manager (LVVWD)

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Joe Leising – Hydrologist II (SNWA)

Zane Marshall – Director-Environmental Resources (SNWA)

Tom Maher – Senior Resource Analyst (SNWA)

Larry Tamashiro – Resource Analyst (SNWA)

Todd Tietjen – Limnology Project Manager (SNWA)

Jim Watrus – Senior Hydrologist (SNWA)

Gary Wood – Renewable Energy Program Manager (SNWA)

APPENDIX B – CONSEQUENCE MATRIX

The following table contains the consequence category definitions and levels defined during the exercise.

Category	Utility Business Impacts	Utility Operational/ Equipment Damage	Source/Receiving Water Impacts	Environmental Impacts	Community/Work Force Health Impact
Description	Revenue or operating income loss evaluated in terms of the magnitude and recurrence of service interruptions.	Costs of replacing the service equivalent provided by a utility or piece of equipment evaluated in terms of the magnitude of damage (minimal, minor, significant, complete loss) and financial impacts (flexible cost scale, "$X," can be customized by each user)	Degradation or loss of source water or receiving water quality and/or quantity evaluated in terms of the recurrence (minimal, temporary, seasonal or episodic, long-term)	Evaluated in terms of environmental damage or loss (aside from source water or other assets) and compliance with environmental regulations (minimal, short term, persistent / permit violations significant impact and/or regulatory enforcement and actions)	Evaluated in terms of the duration (short or long-term) and extent (minimal, minor, localized, or widespread)
Very High	Long-term and/or significant loss of expected revenue or operating income or need for significant capital investment > $5,000,000. Increase in operational expenses (difficulty recruiting, increased power cost)	Complete loss of asset; replacement costs of >$5,000,000 (e.g., need to expand capacity to meet higher peak demands, or need for improved operational flexibility; loss of Intake 2/3 pumping	Long-term compromise of water quality and/or quantity (specifically: reduced gw recharge, increased ET, long-term extraordinary shortage condition on CR)	Significant environmental damage - may incur regulatory action (e.g., climate changes baseline environment considered in ESA, making it more difficult for action agency to be in compliance)	Long-term and/or widespread public health impacts. Health impact that results in a single death (e.g., loss of life in a fire)
High	Seasonal or episodic - but minor - compromise of expected revenue or operating income, or need for large capital investments $1,000, 000 - $5,000,000	Significant damage to equipment; costs estimated at $1,000,000-$5,000,000 ($1,000,000 is insurance deductible for losses other than earth movement, flooding, or weather)	Seasonal or episodic compromise of water quality and/or quantity (reduced gw recharge, increased ET, 3 consecutive years of 40kafy shortage on CR)	Persistent environmental damage - may incur regulatory action	Short-term and localized public health impacts
Medium	Minor and short-term reductions in expected revenue or operating income, or the need for capital investments between $100,000 and $1,000,000. This could include lowering pumps (~$100,000 per pump)	Minor damage to equipment; costs estimated at $100,000-$1,000,000 (need to adjust pump levels to low water levels)	Temporary impact on water quality and/or quantity (quality +/or quantity of local gw aquifers reduced, 3 consecutive years of 20kafy shortage on CR)	Short-term environmental damage - compliance can be quickly restored (e.g., flood event temporarily changes temp & turbidity for key habitats)	Minor public health impacts (more challenges for treatment)
Low	Minimal potential for any attributable loss of revenue or operating income, and capital investment requirements are <$100,000	Minimal damage to equipment (<$100,000)	No more than minimal changes to water quality and/or quantity	No and low impact or environmental damage	No and low impact on public health

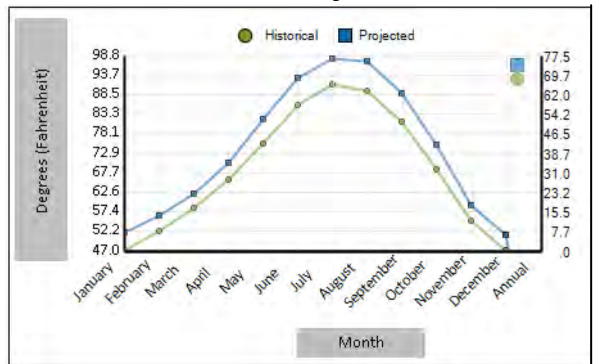
APPENDIX C – CLIMATE SCENARIO DATA

The following plots and tables contain the climate data for scenarios defined during the exercise.

Hot and dry model projection: Projected climate conditions for 2060

Average Temperature Data (F)

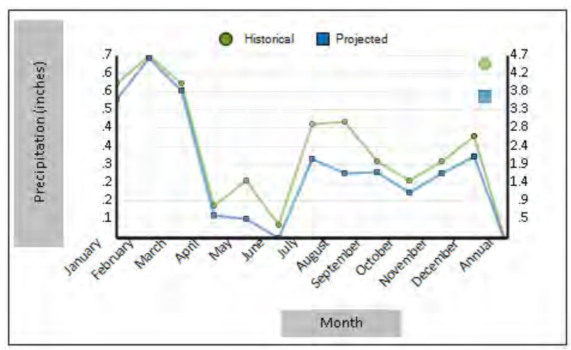
Annual	73.79
JAN	52.00
FEB	56.52
MAR	62.17
APR	70.19
MAY	81.81
JUN	92.98
JUL	97.86
AUG	97.45
SEP	88.63
OCT	75.02
NOV	59.25
DEC	51.37



Individual symbols in upper-right of graphs indicate historical and projected annual averages.

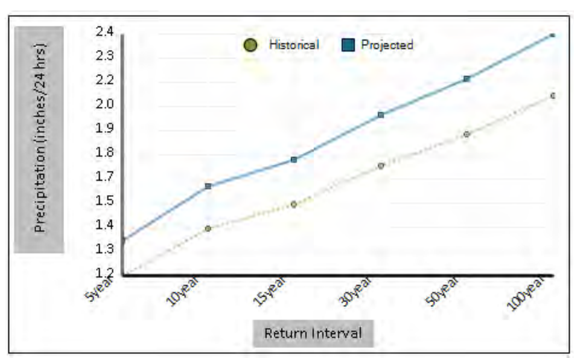
Total Precipitation Data (inches)

Annual	3.66
JAN	0.53
FEB	0.68
MAR	0.56
APR	0.11
MAY	0.10
JUN	0.03
JUL	0.32
AUG	0.27
SEP	0.27
OCT	0.20
NOV	0.26
DEC	0.32



Total precipitation (in) during 24-h event

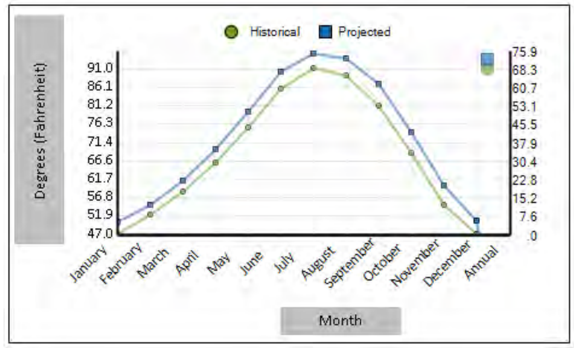
Return interval	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
5-y	1.36	0.86	0.63	0.90	0.86
10-y	1.63	1.04	0.90	1.40	1.13
15-y	1.76	1.13	1.04	1.76	1.27
30-y	1.99	1.31	1.36	2.49	1.49
50-y	2.17	1.45	1.58	3.21	1.67
100-y	2.40	1.58	1.99	4.57	1.95



Central model projection: Projected climate conditions for 2060

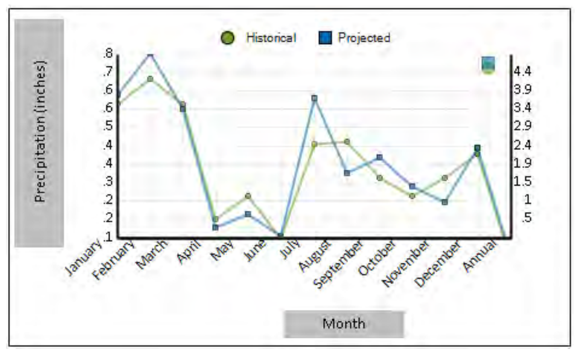
Average Temperature Data (F)

Annual	72.28
JAN	50.47
FEB	55.03
MAR	61.34
APR	69.71
MAY	79.79
JUN	90.32
JUL	94.93
AUG	93.8
SEP	86.99
OCT	74.21
NOV	59.91
DEC	50.64



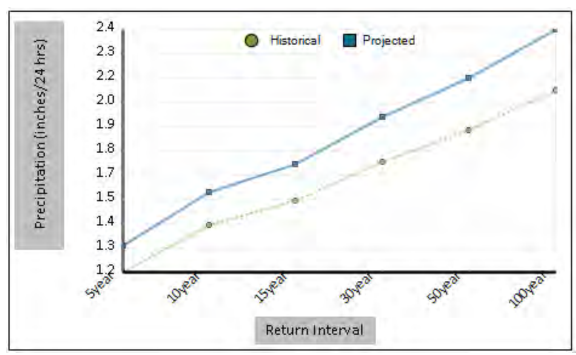
Total Precipitation Data (inches)

Annual	4.61
JAN	0.63
FEB	0.78
MAR	0.57
APR	0.12
MAY	0.17
JUN	0.09
JUL	0.62
AUG	0.33
SEP	0.39
OCT	0.28
NOV	0.22
DEC	0.43



Total precipitation (in) during 24-h event

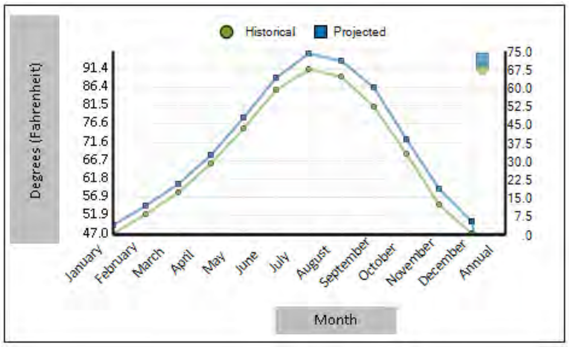
Return interval	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
5-y	1.31	0.83	0.61	0.87	0.83
10-y	1.58	1.01	0.88	1.36	1.10
15-y	1.72	1.10	1.01	1.72	1.23
30-y	1.95	1.29	1.33	2.44	1.47
50-y	2.15	1.43	1.56	3.17	1.65
100-y	2.39	1.58	1.99	4.56	1.94



Warm and wet model projection: Projected climate conditions for 2060

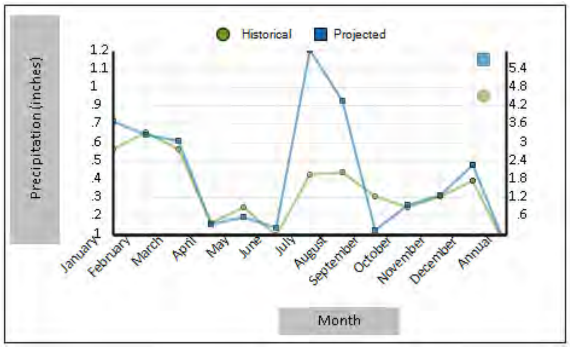
Average Temperature Data (F)

Annual	71.45
JAN	49.45
FEB	54.47
MAR	60.51
APR	68.12
MAY	78.35
JUN	89.04
JUL	95.34
AUG	93.49
SEP	86.54
OCT	72.35
NOV	59.05
DEC	50.4



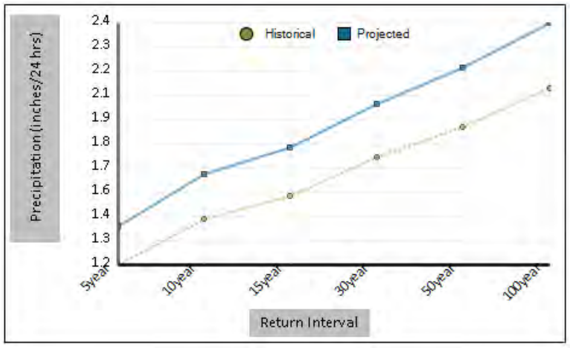
Total Precipitation Data (inches)

Annual	5.67
JAN	0.76
FEB	0.67
MAR	0.64
APR	0.14
MAY	0.19
JUN	0.12
JUL	1.18
AUG	0.88
SEP	0.1
OCT	0.25
NOV	0.32
DEC	0.49



Total precipitation (in) during 24-h event

Return interval	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
5-y	1.38	0.87	0.64	0.92	0.87
10-y	1.65	1.05	0.91	1.42	1.14
15-y	1.78	1.14	1.05	1.78	1.28
30-y	2.01	1.33	1.37	2.51	1.51
50-y	2.20	1.46	1.60	3.25	1.69
100-y	2.43	1.60	2.02	4.63	1.97



Appendix D – Scenarios with Threat Likelihoods

The following table contains the level of likelihood assessed for each threat, from Low to Very High, in each time period and scenario.

	Likelihood (Hot & Dry)		Likelihood (Central)		Likelihood (Warm & Wet)	
Threats	**2035**	**2060**	**2035**	**2060**	**2035**	**2060**
Changes in SNWA energy use and availability	n/a	High	n/a	Medium	n/a	Low
Changes in residential use	Medium	Medium	Medium	Medium	Medium	Medium
Poor power grid performance	Medium	Medium	Medium	Medium	Medium	Medium
Runoff timing	n/a	n/a	Medium	Medium	Low	Medium
Reduced snowpack	High	High	Medium	High	Medium	Medium
Lower lake and reservoir levels	High	High	Medium	High	Low	Medium
Extreme low lake level	Low	Medium	Low	Medium	Low	Low
Reduced groundwater recharge	n/a	Medium	n/a	Medium	n/a	Medium
High temperatures	Very High	Very High	High	High	High	High
Warmer water temperatures	High	High	High	High	High	High
Altered water quality	High	High	Medium	High	Medium	High
High flow events	High	High	High	High	High	High
Wildfire	Medium	Medium	Medium	Medium	Medium	Medium
Loss of wetlands	Medium	Medium	Medium	Medium	Medium	Medium
Unhealthy environment	Medium	Medium	Medium	Medium	Medium	Medium
Water cost	Medium	Medium	Medium	Medium	Medium	Medium
Living cost	Medium	Medium	Medium	Medium	Medium	Medium
Invasive species	Medium	Medium	Medium	Medium	Medium	Medium

APPENDIX E - BASELINE ANALYSIS – PRELIMINARY RESULTS

The following table lists the preliminary baseline analysis results, using highest consequence level method, for the Hot and Dry climate scenario (Scenario 1). Consequence levels range from green (lowest risk) to red (highest risk). Source water refers to consequences that impact quality or quantity of water.

Hot and Dry Climate Scenario

Threat	Asset	Time Period	Consequence Levels: Business	Equipment or Facility	Source Water	Environmental	Community	Overall Result	RRUs
Lower lake and reservoir levels	Intakes and raw water conveyance system	2035	Low	Medium	Low	Low	Low	Medium	45
		2060	Medium	Medium	Low	Low	Low	Medium	45
	Lake Mead (Colorado River Resource)	2035	Low	Low	Medium	Medium	Low	Medium	45
		2060	Low	Low	Low	Low	Low	Low	40
	Power Supply (In Valley)	2035	Medium	Medium	Medium	Medium	Medium	Medium	45
		2060	High	High	High	High	High	High	55
	SNWA Water Treatment Systems	2035	Medium	Medium	Medium	Low	Low	Medium	45
		2060	Medium	Medium	Medium	Low	Low	Medium	45
	Las Vegas Valley Aquifers	2035	High	High	High	Low	Low	High	55
		2060	High	High	Very High	Low	Low	Very High	75
Extreme low lake level	Intakes and raw water conveyance system	2035							
		2060							
	LVVWD Distribution Grid and Conveyance	2035	High	High	Low	Low	Low	High	40
		2060	High	High	Low	Low	Low	High	45
	Lake Mead (Colorado River Resource)	2035	Low	Low	High	Low	Low	High	40
		2060	Low	Low	High	Low	Low	High	45
	SNWA Water Treatment Systems	2035	High	High	Very High	Low	Low	Very High	50
		2060	High	High	Very High	Low	Low	Very High	60

Hot and Dry Climate Scenario

Threat	Asset	Time Period	Consequence Levels: Business	Equipment or Facility	Source Water	Environmental	Community	Overall Result	RRUs
Poor power grid performance	Las Vegas Valley Aquifers	2035	High	High	High	Low	Low	High	55
		2060	High	High	Very High	Low	Low	Very High	75
	Intakes and raw water conveyance system	2035	Low	Very High	Low	Low	Low	Very High	60
		2060	Low	Very High	Low	Low	Low	Very High	60
	LVVWD Distribution Grid and Conveyance	2035	Low	Low	Low	Low	Low	Low	37
		2060	Low	Low	Low	Low	Low	Low	37
	Power Supply (In Valley)	2035	Medium	Medium	Medium	Medium	Medium	Medium	40
		2060	High	High	High	High	High	High	45
	SNWA Water Treatment Systems	2035	Very High	Very High	Low	Low	Low	Very High	60
		2060	Very High	Very High	Low	Low	Low	Very High	60
Warmer water temperatures	Intakes and raw water conveyance system	2060	Low	High	Low	Low	Low	High	55
	LVVWD Distribution Grid and Conveyance	2035	Low	High	Low	Low	Low	High	55
		2060	Low	High	Low	Low	Low	High	55
	SNWA Water Treatment Systems	2035	Low	Medium	Medium	Low	Low	Medium	45
		2060	Medium	Medium	Very High	Low	Low	Very High	75
Altered water quality	Intakes and raw water conveyance system	2035	Low	Very High	Low	Low	Low	Very High	75
		2060	Low	Very High	Low	Low	Low	Very High	75
	SNWA Water Treatment Systems	2035	Low	Medium	Medium	Low	Low	Medium	45
		2060	Low	Medium	Medium	Low	Low	Medium	45
Changes in residential use	Intakes and raw water conveyance system	2035	Low	Low	Low	Low	Low	Low	37
		2060	Low	Low	Low	Low	Low	Low	37
	LVVWD Distribution	2035	Low	Low	Low	Low	Low	Low	37

Hot and Dry Climate Scenario

Threat	Asset	Time Period	Consequence Levels: Business	Equipment or Facility	Source Water	Environmental	Community	Overall Result	RRUs
	Grid and Conveyance	2060	Low	Low	Low	Low	Low	Low	37
	Power Supply (In Valley)	2060	Low	Low	Low	Low	Low	Low	37
	SNWA Water Treatment Systems	2035	Low	Low	Low	Low	Low	Low	37
		2060	Low	Low	Low	Low	Low	Low	37
	Las Vegas Valley Aquifers	2060	Medium	Medium	Medium	Low	Low	Medium	40
High flow events	LVVWD Distribution Grid and Conveyance	2035	Low	Low	Low	Low	Low	Low	40
		2060	Low	Low	Low	Low	Low	Low	40
	Power Supply (In Valley)	2035	Medium	Medium	Low	Low	Low	Medium	45
		2060	Medium	Medium	Low	Low	Low	Medium	45
	SNWA Water Treatment Systems	2035	Medium	Medium	Medium	Low	Low	Medium	45
		2060	Medium	Medium	Low	Low	Low	Medium	45
Invasive species	Intakes and raw water conveyance system	2035	Low	Medium	Low	Low	Low	Medium	40
		2060	Low	Medium	Low	Low	Low	Medium	40
	SNWA Water Treatment Systems	2035	Low	Medium	Medium	Low	Low	Medium	40
		2060	Low	Medium	Medium	Low	Low	Medium	40
Reduced groundwater recharge	Las Vegas Valley Aquifers	2060	Low	Medium	Medium	Low	Low	Medium	40

APPENDIX F – EXISTING ADAPTIVE MEASURES

The following table lists some of the adaptive measures defined in the CREAT analysis with the assets and threats where they were used (selected) during assessments.

	Altered water quality	Changes in residential use			Extreme low lake level			Lower lake and reservoir levels			Poor power grid performance			Warmer water temperatures		
Existing Measures for Intakes	**S1**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
Ambient water temperature monitoring														X		
Back-up power											X	X				
Demand management											X	X	X			
Diversify power supply											X	X				
Drought contingency plan								X	X	X						
Emergency response plan – water supply (power)											X	X	X			
Energy efficiency improvements											X	X	X			
Groundwater / aquifer recharge		X	X	X												
Groundwater Monitoring Program (Includes In Valley and CLWP)								X	X	X						
Keep all ground water available		X	X	X												
Leakage reduction program		X	X	X												
New third intake											X	X				
Optimize well system														X		
Optimized chemical use	X															
Optimized pumping								X	X	X	X	X	X			
Stakeholder engagement											X	X	X			
Storm storage (capture excess CR flows)		X	X	X												
Water quality models (dist sys in-house)	X															

	Altered water quality	Changes in residential use			Extreme low lake level			Lower lake and reservoir levels			Poor power grid performance			Warmer water temperatures		
Existing Measures for Lake Mead	**S1**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
Access LVV bank					X			X								
Additional demand management					X			X								
CLWP Groundwater Development Project					X			X								
CRBS Options for CR System benefit					X			X								
CRBS Options for Nevada benefit					X			X								
Expand groundwater monitoring program (Includes In Valley and CLWP)					X											
Interconnections					X											
Maintain interim supplies (bank recovery and/or ICS)					X	X	X	X	X	X						
Optimize use of the 3rd intake					X			X								
Regional electricity demand models					X			X								
Strengthen drought contingency plan					X			X								
Strengthen leakage reduction program					X			X								
Supply-demand models					X			X								
Weather forecast monitoring					X			X								
Existing Measures for Treatment	**S1**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
Adaptive rates								X								
Add advanced treatment (Microfiltration/RO) (Altered treatment)														X		
Add chloramination (Altered treatment)														X		
Addtl flood control - dirt levees				X												
Addtl flood control - Long-term project				X												
Alternate water supplies								X								
CLWP Groundwater Development Project														X		
Community outreach								X								

	Altered water quality	Changes in residential use			Extreme low lake level			Lower lake and reservoir levels			Poor power grid performance			Warmer water temperatures		
Existing Measures for Treatment (cont.)	**S1**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
Demand management								X				X	X			
Development code changes								X								
Effluent re-use								X								
Energy efficiency improvements											X	X	X			
Improve well use optimization														X		
Increase air stripping dist sys (Altered treatment)														X		
Install influent cooling systems (Altered treatment)														X		
New third intake								X				X	X			
Optimized pumping											X	X	X			
Point of use DW treatment (carbon/filt)														X		
Stakeholder engagement								X				X	X			
Water resource acquisition					X											
Existing Measures for Distribution	**S1**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
Add chloramination (Altered treatment)														X		
Additional water quality model runs (Lake only)														X		
Air stripping with dist sys (Altered treatment)														X	X	X
Alt water supply (bottled water, etc.)															X	
Aquifer recharge for water age manag															X	
CLWP Groundwater Development Project														X		
Connect to CLWP GW Devel Proj															X	
Deeper intake (upstream pipeline)															X	
Demand management								X	X	X						
Dist sys temperature monitoring														X	X	X

	Altered water quality	Changes in residential use			Extreme low lake level			Lower lake and reservoir levels			Poor power grid performance			Warmer water temperatures		
Existing Measures for Distribution (cont.)	**S1**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
Emergency response plan – water supply					X	X	X									
Expand distribution flexibility		X	X	X												
Groundwater models (LVV)														X	X	X
Improve well use optimization														X		
Increase air stripping dist sys (Altered treatment)														X		
Leakage reduction program					X	X	X	X	X	X						
New technol or chemicals (treatment)															X	
Optimize use of the 3rd intake														X		
Point of use DW treatment (carbon/filt)														X		
R&D predictive methods / ID critical factors															X	
Regulatory flexibility															X	
Regulatory flexibility (lite)															X	
Temperature monitoring														X		
Water quality models (dist sys in-house)														X	X	X

Appendix G - Adaptation Packages

The following table lists the preliminary adaptation packages discussed during exercise, each based on a trigger or threshold related to assessed threats.

Adaptation Package Description	Short-term package for challenge with lake water quality	Long-term package for challenge with lake water quality	Short-term package for challenge with temperature mgmt in distribution system	Long-term package for challenge with temperature mgmt in distribution system	Package to address temperature challenge beyond all other options
Triggers/ Thresholds	Increased algal blooms Lower lake levels Decreased dissolved oxygen	Increased algal blooms Lower lake levels Decreased dissolved oxygen	Increased trihalomethanes Resident water outage Taste and odor complaints	Increased trihalomethanes Resident water outage Taste and odor complaints	Regulatory violation
Adaptive Measures	Additional water quality modeling R&D to identify critical factors Monitor temperature Monitor weather Optimize third intake	Alter treatment by adding chloramination CBRS options for CR benefit Supply and demand models New technology/chemicals Advanced treatment (microfiltration/RO) Regulatory flexibility (Phase I)	Improve well use optimization R&D to identify critical factors Increase air stripping Aquifer recharge for water management Management of chloramination Maintain partnerships with land developers Volume reduction mgmt	Connect to CLWP groundwater project Add chloramination to treatment Aquifer recharge for water management Maintain partnerships with land developers New technology/chemicals Access LVV GW bank Regulatory flexibility (Phase I)	Install influent cooling system Extend third intake deeper into lake Point of use treatment / supply bottled water Pursue regulatory flexibility (Phase II)

Appendix H - Recommendations for Future Tool Development and Training

Overall

- Develop separate tracks for basic versus advanced users, possibly several opportunities where users can throw the switch to go to the alternate track
- Check accessibility of training videos
- Add Equal button to consequence weighting screen

Baseline and Resilience Analysis

- Include a way to filter analysis summary trees to just show current work (default should be to show all so you can identify gaps)
- Refine adaptive measure contribution screen
- Percentages for adaptive measure contribution screen are not intuitive, change method here to rank order, rank weight or other means or comparison (for interface, consider click and drag or star system, also consider adding positive and negative switch)
- Add scale of likelihood of implementation
- Add note for options to be used 'if-available' (e.g. for groundwater development project)
- Add note or guidance regarding the need to consider likelihood of implementation in addition to (as part of) any cost-benefit analysis
- Add import of 2035 adaptive measures to 2060 analysis (SNWA group kept having to re-populate the same measures)

Planning

- Add a drop down to allow user to put in their description of cost info (adaptive measure screen)
- Add an option to go back and modify or split adaptive measures during Adaptation Planning
- Update energy and green infrastructure options in CREAT with those from updated Adaptation Strategies Guide
- Identify method to modify adaptive measures ad hoc (e.g., during Planning)
- Include button to grab all adaptive measures related to each asset to avoid the repetition of considering adaptive measures related to analyses again during package design

Results and Reports

- Add interim products, or exports of results to encourage users and document progress
- Add functionality to display results under different assumptions
- Add functionality for right-click to generate report for a specific asset

- Add functionality to track items that need to be modified (e.g., flag items and add comments about future modifications), consider adding comment report
- Add check on generated reports to highlight areas that need to be re-visited (SNWA assessment and costs not complete)

With regard to future training and tool guidance, SNWA suggested that EPA:

- Consider developing a training module or class to train utility representatives.
- Explore additional ways to facilitate group collaboration (e.g., other ways to enter data into the tool, such as importing MS Excel spreadsheets, coupled with hands-on time with the tool). Participants noted that interacting with the tool during the exercise greatly increased their understanding of how it worked.
- Consider providing a facilitation package (e.g., PowerPoint presentations, worksheets, Excel templates and fact sheets describing common pitfalls and how to avoid them).
- Consider ways to convey information to utilities regarding the time commitment involved in conducting a full risk assessment.
- Emphasize that CREAT is focused on assessing effectiveness of adaptation plans and that other considerations such as financial capacity, trade-offs and political feasibility are not explicitly taken into account.

Climate Resilience Evaluation and Awareness Tool (CREAT) Exercise with Southern Nevada Water Authority

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